Los Angeles Pilot Project Using Japanese Earthquake Resistant Joint Ductile Iron Pipe

Los Angeles Department of Water & Power
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  – Implementation plan
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LADWP OVERVIEW

- Largest Municipal Utility in USA
- Founded 1902
- Serves 4.1-million people
  - 712,000 water service connections
- 1214-square kilometer service area
- Receives water from:
  - 4 aqueducts
  - Local wells
- LADWP owns and operates the water and power systems
Los Angeles water supply and transmission subsystems showing major facilities and 1994 damages

Water System Performance in 1994 Northridge Earthquake

- **Water System Damages**
- 14 repairs to the raw water supply conduits
- 60+ repairs to treated water transmission pipes
- 1013 repairs to distribution pipe
- > 200 service connection repairs
- 7 damaged tanks
- Temporary suspension of half the treatment plant service
- Power lost throughout City
- **$41 million total repair costs**
1994 L.A. DELIVERY SERVICES

- 159,434 service connection outages
- 22% of all services
- ~670,000 residents
- All delivery service restored in 7 days
- Pipe repairs completed several weeks later
Network Resilience by Incorporating Seismic Resistant Distribution Pipes

- Identify pipe materials and joint types that provide adequate seismic resistance
- Identify critical/important distribution pipes
- Replace critical pipes based on seismic risk and in collaboration with the Asset Management and Pipe Replacement Programs
- Recognize earthquake damages and water service outages will occur
  - entire network cannot be cost-effectively replaced in near term
- Develop plan to ensure water service restorations achieve community resilience within an acceptable timeframe
  - Focus on most critical water restorations first
- Develop long-term network improvement program (e.g. 25 to 50 years)
Earthquake Resistant Ductile Iron Pipe

Comparison of Joint Structure

**General Joint**
(Flexible Joint)

- Rubber Gasket
- T-type
- Expand
- Deflect

No Expansion if lock joint used

**Earthquake-Resistant Joint**
(Chain structure Joint)

- Rubber Gasket
- Lock Ring
- Spigot Projection
- NS-type
- Expand / Contract
- Deflect
- Lock

Earthquake Resistant Ductile Iron Pipe
## ERDIP Characteristics

<table>
<thead>
<tr>
<th>Property</th>
<th>Performance</th>
<th>ISO 16134</th>
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</thead>
<tbody>
<tr>
<td>Amount of expansion/contraction</td>
<td>±1% of L</td>
<td>Class S-1</td>
</tr>
<tr>
<td>Slip-out resistance</td>
<td>3D kN</td>
<td>Class A</td>
</tr>
<tr>
<td>Joint deflection angle</td>
<td>6—8°</td>
<td></td>
</tr>
</tbody>
</table>

Note)  
- **L**: Nominal pipe length (millimeters)  
- **D**: Nominal diameter of pipe (millimeters)  

*1) Joint deflection angles depend on pipe diameters.

- **No Damage or Leaks** after 40-years of use  
- Experienced many large Japanese earthquakes  
- Subjected to several meters of permanent ground deformation
# Diameter range of the earthquake resistant joints

<table>
<thead>
<tr>
<th>Joint Type</th>
<th>Diameter Range (mm/inch)</th>
<th>GENEX</th>
<th>NS</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>75~250mm (3”~10”)</td>
<td>500~2000mm (20”~80”)</td>
<td>500~2600mm (20”~102”)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75~450mm (3”~18”)</td>
<td>500~2000mm (20”~80”)</td>
<td>500~2600mm (20”~102”)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500~1000mm (20”~30”/3.3’)</td>
<td>500~2000mm (20”~80”)</td>
<td>500~2600mm (20”~102”)</td>
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<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
### The 2011 Great East Japan Earthquake

#### Overview of Damages on Water Pipelines

<table>
<thead>
<tr>
<th></th>
<th>Water works bureau</th>
<th>Water supply population</th>
<th>Maximum seismic intensity</th>
<th>Pipeline length (km)</th>
<th>Number of damages</th>
<th>Damage rate (/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Sendai City</td>
<td>1,017,407</td>
<td>6U</td>
<td>3,732</td>
<td>276</td>
<td>0.07</td>
</tr>
<tr>
<td>B</td>
<td>Miyagi Pref.</td>
<td>1,852,000</td>
<td>6U</td>
<td>333</td>
<td>35</td>
<td>0.11</td>
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<tr>
<td>C</td>
<td>Ishinomaki</td>
<td>200,025</td>
<td>6U</td>
<td>1,561</td>
<td>212</td>
<td>0.14</td>
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<tr>
<td>D</td>
<td>Chiba Pref.</td>
<td>2,928,062</td>
<td>6L</td>
<td>8,696</td>
<td>446</td>
<td>0.05</td>
</tr>
<tr>
<td>E</td>
<td>Mito City</td>
<td>264,133</td>
<td>6L</td>
<td>1,717</td>
<td>139</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Seismic intensity in J.M.A. scale

**Epicenter**
Pipe material comparison

- DIP is more reliable material than others.
- ERDIP suffered no damage the same as previous big earthquake.
Damaged points and liquefied areas along Tokyo Bay

Many damages of pipelines occurred in the liquefied areas

Source:
(Left drawing) map: Geospatial Information Authority of Japan.
Landform classification: National Research Institute for Earth Science and Disaster Prevention
(Right drawing) Ministry of Land, Infrastructure, Transport and Tourism, Regional Development Bureau
ERDIP suffered no damages in liquefied area

ERDIP suffered no damages in the liquefied areas where many damages occurred at water pipelines
DN150, 200 NS-type (Landslide of Road by Tsunami)
DN350 NS-type DIP at Water Bridge
SII, NS-type DIP Withstand Large Ground Subsidence

Ground Subsidence

Subsidence (1.3m)

DN300 SII-type

Liquefaction

DN150 NS-type
SII, NS-type DIP withstand Landslide by typhoon

Landslide at Road

DN400 SII-type

DN150 NS-type
LADWP
Earthquake Resistant Joint
Ductile Iron Pipe
Pilot Project
Pilot Project using Earthquake Resistant Joint Ductile Iron Pipe (ERDIP)

- The ERDIP is 1 of several pipes that meets the proposed criteria for investigating use in LA for seismic resistance
  - Other pilot projects are being undertaken with HDPE and PVC
- Kubota and LADWP have collaborated to implement a pilot project to install ERDIP in Los Angeles
- Currently ERDIP only available and used in Japan
- LADWP is the 1st to use in USA
- Additional advantages (other than seismic)
  - Landslide risks
  - Erosion
  - Thermal stresses
  - Overall, the ERDIP may provide significant infrastructure reliability above the seismic risk
Pilot Project Purpose

- Purpose of pilot project is to:
  - Allow the LADWP to become acquainted with the ERDIP
  - Obtain direct observations and experience of the design and installation procedures
  - Compare the design and installation of ERDIP with pipes normally installed by LADWP
  - Make our own assessment on suitability for using the ERDIP to improve network reliability
  - Determine if ERDIP is helpful for improving the LA Water Infrastructure
Pilot Project Outline

1. **Presentation**
   1) Kubota sends pipes from Japan.
   2) Kubota gives a presentation and demonstration on ERDIP (NS and GENEX models) pipe in Los Angeles.

2. **Develop the pilot project plan**
   1) LADWP settles the details of the pilot project (pipe diameter, length, schedule, etc).
   2) LADWP’s management approves the project plan.

3. **Preparation for installation**
   1) Kubota supports the pipeline design phase with training and reviews.
   2) Kubota makes installation manual, and helps to addresses items needed to meet local requirements.
   3) Agreement of purchase conditions between LADWP and Kubota.

4. **Production and Export (from Kubota)**
   1) Kubota produces pipe.
   2) Export and transport (logistic, stock yard, etc).
   3) Procure the fittings for joints between JWWA\(^1\) pipe and AWWA\(^1\) pipe standards.

5. **Construction**
   1) Kubota dispatches the pipe installation instructors from Japan.
   2) Kubota provides training for field crews appointed by LADWP.
   3) LADWP undertakes construction using their own field crews.

6. **Feedback**
   1) LADWP compiles the evaluation (design, construction, cost, etc).
   2) Kubota improves NS and GENEX for US market, (if necessary).

7. **Present Results**
   1) LADWP announces the achievement of pilot project.

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\(^1\)Japan Water Works Association
\(^2\)American Water Works Association
Pilot Project Site Selection

• **For 1st two sites**: Identify areas damaged by ground failure during the **1994 Northridge Earthquake**
  – Balboa Blvd
  – Reseda Blvd Region
  – Studio City/Sherman Oaks Region

• Review pipe layout
• Compare with planned pipe replacements
• Select pipes to be replaced as part of pilot project
• Implement pilot project in a manner consistent with a long-term seismic improvement program.

• Currently have two pilot sites
  – Reseda Blvd. (Relatively level ground in San Fernando Valley)
  – Contour Drive (Sloped and curvy roads in Studio City)

• Select **additional pilot project sites** using **resilience criteria**
  – West LA
  – Central LA
  – Harbor
Pilot Project Locations Considered

- Balboa Blvd region
- Roscoe Blvd region
- Sherman Oaks/Studio City region
Main Replacement
Contour Drive

- LADWP originally planned to replace ~1750’ of 6” line;
- 157 psi (1.1 Mpa)
- Proposed pilot to include ERJDIP
- Training performed 1/15 to 1/18/13
- Initiated Construction on 1/28/13
- 1752’ installed
- ERDIP installation completed on April 30, 2013 (53 work days)
Steps Taken to Implement Pilot Project

• Learned about ERDIP over past decade
• Met with Kubota Corp. (Mr. Toshima) in October 2011
  – Identified opportunity for pilot project
• Concept encouraged by LADWP managers
Kubota ERDIP Presentation and Demonstration

- LADWP-Kubota meetings held in LA on January 23-25, 2012
- Presentation and demonstration held in Los Angeles on January 24, 2012
  - Invited guests from waterworks community
  - Over 110 attended from 17 organizations
  - Support from WRF
- Demonstration allowed LADWP hands-on learning experience with GENEX
  - Positive feedback

LADWP crews demonstrating GENEX Pipe assembly

LADWP-Kubota team

Mr. Hara, Kubota Engineer

Mr. Toshima, Kubota Manager
Pipe Design, Contour Drive

- Design
  - Training by Kubota Engineers
  - Design performed by LADWP Engineers
  - Design checked by Kubota Engineers
Pipe Design, Contour Drive
Steps Taken to Implement Pilot Project

• Worked with Kubota on:
  – Pipe layout plans and design changes
  – AWWA to JWWA adaptors
  – Installation procedures
  – Specifications
  – Backfill requirements (sand vs cement slurry)

• Worked closely by email

• Follow up meetings held in LA on:
  – August 7, 2012
  – October 17, 2012
Procurement and Delivery

- Procurement
  - Informal contract (>$150,000)
  - Sole source
  - Ordered extra materials for:
    - Training
    - Field alterations
- Delivery in December, 2012
Technology Exchange

• LADWP traveled to Japan Nov. 2012
  – Engineer
  – Distribution Manager
  – Field/Training Supervisor
• Meet with:
  – Kobe Waterworks Bureau
  – Sendai Waterworks Bureau
  – Kyoto University
• Direct exchange of information at equal levels
• See earthquake damages and pipe performances
• Observe ERDIP installation by Japanese
• Visit Kubota manufacturing plant for ERDIP
Cultural Exchange

Sendai Beef

Nanzen Temple, Kyoto

Sendai

Sushi
Cultural Exchange

Kobe Beef

Kobe elementary school, emergency evacuation center
Training and Installation in LA
LADWP Installation Video
## Near-term criteria

<table>
<thead>
<tr>
<th>Item</th>
<th>Criteria</th>
<th>Status as of July 1, 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acceptance of Concept</td>
<td>Achieved</td>
</tr>
<tr>
<td>2</td>
<td>Application to network resilience</td>
<td>Able to meet concept outline</td>
</tr>
<tr>
<td>3</td>
<td>Ability to learn about the technology application</td>
<td>Achieved, January 2012</td>
</tr>
<tr>
<td>4</td>
<td>Ability to perform engineering design for ERDIP</td>
<td>Achieved by LADWP staff</td>
</tr>
<tr>
<td>5</td>
<td>Ability to purchase pipe</td>
<td>Achieved Fall 2012</td>
</tr>
<tr>
<td>6</td>
<td>Ability to train and certify installation crews for ERDIP</td>
<td>Achieved January 2013</td>
</tr>
<tr>
<td>7</td>
<td>Ability to adopt local installation procedures to the ERDIP technology (e.g., slurry trench fill)</td>
<td>Achieved, Summer 2012</td>
</tr>
<tr>
<td>8</td>
<td>Field crew ability to install correctly</td>
<td>Achieved, Feb./March 2013</td>
</tr>
<tr>
<td>9</td>
<td>Positive acceptance from LADWP Distribution Division (Management and supervisor levels)</td>
<td>Achieved, management, supervision, and const. crews interviewed May 9, 2013.</td>
</tr>
<tr>
<td>10</td>
<td>Installation rate (feet per day)</td>
<td>Acceptable, similar compared to other similar projects.</td>
</tr>
<tr>
<td>11</td>
<td>Project cost in comparison with other pipe projects (standard DIP, steel, nonmetallic, etc.)</td>
<td>Acceptable, within an acceptable range at pilot stage.</td>
</tr>
<tr>
<td>12</td>
<td>Workability (the degree of ease the material can be cut, shaped or smoothed by hand or machines and capable of being put into effective operation)</td>
<td>Acceptable and overall positive input from field crews.</td>
</tr>
</tbody>
</table>

## Long-term Criteria:

1. Investigation corrosion resistance of GenEx coating
2. Actual seismic performance*

*Seismic performance is not a criterion for accepting use of this pipe on a full scale production level. We must accept the documented positive performance in Japan of no breaks or leaks for nearly 40 years.
PILOT PROJECT RESULTS
CONTOUR DRIVE

• Costs
  – **Construction**: 8% to 13% increase, mostly from material cost.
  – **Engineering**: cost about doubled, increased total project cost by ~7%.
  – **Project**: 15% to 20% total project cost increase.

• Workability
  – Construction crews found the material to be very workable, in some cases easier than the Tyton joint pipe normally placed by the LADWP
  – The tools are very good, easy to use, and helped make installation go smoothly. Smooth Process:
    • Removed straining and as a result eliminated injuries that otherwise can occur when forcing the pipe spigot into the bell, &
    • Prevented rolling the gaskets out of the bell.
LADWP Outreach

• Purpose:
  – provide others an opportunity to learn from the LADWP pilot project while it was being undertaken
  – educate other water agencies, associations, universities, and consulting firms about the ERDIP in case it may be useful for them

• Demonstration project, January 2012
  – Over 100 participants from LADWP, other agencies, consultants, and Universities

• Site Visits, February and March 2013
  – 7 site tours
  – Attendees included 60 people from 17 organizations (not including LADWP or Kubota)
Site Visit Outline

• 10:00AM 1.5-hour presentation covering:
  – Background and purpose for using the ERJ-DIP, and
  – Plan and purpose of the LADWP Pilot Project
  – Questions and Answers

• 11:30 PM Lunch in cafeteria (on your own)

• 12:15 PM Take LADWP vans to the site

• 1:00 PM View placing and jointing the pipe.
  – Communication with LADWP installation supervisor.

• 2 to 2:30 Depart site and return to JFB.
  – End of meeting.
Media Attention

- Los Angeles ERDIP Pilot project has captured attention of international media
- 9 News Paper articles
  - 7 in Japan
  - 2 in USA (LA Daily News & Wall Street Journal)
- 7 Television broadcasts
  - 3 in Japan
  - 1 in San Francisco (KTVU)
  - 3 International (NHK World)
Los Angeles Tests Water Pipes That Stand Up to Quakes

By Harriet Sos

Los Angeles has a come up with a strategy to prepare for the Big One: earthquake-proof water pipes made only in Japan.

The Los Angeles Department of Water and Power recently finished installing a test patch of about 2,000 feet of a special kind of iron piping in the San Fernando Valley.

The piping, made by Japan's Keihatsu Corp. and designed to withstand ground deformation, has endured 40 years of earthquakes in Japan—including the 9.0-magnitude Tohoku earthquake that struck in 2011, triggering a tsunami.

Unlike traditional water pipes, these so-called ductile iron pipes are able to withstand quakes because they can bend and flex instead of buckling under pressure. The system is engineered to work like a chain, meaning it doesn't break apart even if its various components are moving.

LADWP supervising engineer Craig Davis learned about the pipes in 2003 and negotiated to import some for the Los Angeles pilot project shortly after the 2011 quake. Mr. Davis said his chief work-crowd trainer to Japan last year and has two Japanese reps on site supervising the Los Angeles installation.

Initially, the city plans to replace only a fraction of its piping—about 3 miles of the total 7,000 miles—with the quake-proof tubes, limiting installation to the most vulnerable, fault line-adjacent areas. The material is expensive, about 2½ times the price of the standard water pipe used in Los Angeles.

The first test installation cost $180,000; the 6,000 feet of piping for the second installation scheduled to start this fall will cost $200,000. To cut expenses, Los Angeles officials are trying to help Keihatsu find a manufacturing partner in the U.S.

The Los Angeles Aqueduct, which channels water to Southern California communities from the Sierra Nevada more than 300 miles away, was built a century ago, and the city has worked to replace and retrofit the system's oldest cast-iron pipes in recent years. LADWP said it has installed 2,290 miles of new pipe since 1993 and replaced 187 miles of pipe since 2006.

But work crews have struggled to keep pace with water-main bursts throughout the city.

Engineers say bursts may have intensified since rates went into effect limiting outdoor plant watering to certain times during the week, meaning more people are watering at the same time, causing increased pressure.

This Japanese quake-proof piping has endured forces like shaking, landslides and extreme temperature swings because it can expand, contract and bend without leaking or pulling apart, said Thomas O'Rourke, an engineering professor at Cornell University who studies such pipes. The flexible joints are still strong enough when they lock up to allow a heavy load of water to flow through the piping.

While some U.S. manufacturers also produce ductile iron pipe, those varieties haven't been designed with quakes in mind, nor have they been tested through nearly as many temblors as in Japan, Mr. O'Rourke said.

Meanwhile, the LADWP is adopting a different kind of plastic-piping technology used in New Zealand to protect Los Angeles' water supply as it crosses the San Andreas fault through a tunnel on its way to the city. Although continuous plastic pipes couldn't be easily integrated into most of the city's cast-iron distribution system, the agency plans to use water through one long tube just as it passes through the Elizabeth Tunnel, which could easily crumble in during a major quake. Construction is slated to begin in the fall on the $4 million project.

"This reduces significantly the risk of losing the water supply to Los Angeles, which would be a real threat to the U.S., not just to Southern California," Mr. O'Rourke said.

In 1994, the 6.7-magnitude Northridge earthquake cost Los Angeles more than $60 million to repair its pipelines and in some cases replaced them entirely, according to the LADWP. It took seven days to get water flowing to all its customers.
Pilot Project Status

Other sites

- Reseda Blvd.
  - ERDIP Design in progress
  - Phase I in progress
    - Installing 1st line of standard DIP
  - Material Procurement method
    - Formal (present to Board of W&P Commissioners)
  - Construction planned to initiate around July 2014

- Western, Central, Harbor
  - In the process of selecting sites for design
Summary

- Kubota ERDIP is one of several potential pipes that can help improve the LADWP distribution network seismic performance
- Pilot project provides:
  - Direct experiences to determine applicability of new technologies into the network
  - Opportunity to apply seismic improvement concepts into the distribution network
  - Incremental seismic improvements
- Distribution network seismic improvements are important for LADWP infrastructure reliability
- **Pilot Project results are positive** so far
Questions?